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IONOSPHERIC RESEARCH

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Semi-Annual Status Report No. 1

for period

October 1, 1975 to March 31, 1976

IONOSPHERE RESEARCH LABORATORY

University Park, Pennsylvania

PSU-IRL-SAR-76/1

Ionosphere Research

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Approved by: ______________________

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INTRODUCTION

This report is a statement of work currently in progress and is intended to meet contractual report requirements. Many of the topics discussed are part of M.S. and Ph.D. thesis programs and great care should be taken in the use of this data. No part of the report should be quoted without the expressed permission of the author.

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1. Planetary Atmospheres

1.1 Thermospheric Processes - J. S. Nisbet

A paper based on a comparison of the 6300 Å airglow temperatures and mass spectrometer density derived temperatures entitled "Global Exospheric Temperatures and Densities Under Active Solar Conditions" has been completed and submitted to Planetary and Space Sciences. This paper reconciles the very large differences between the exospheric temperatures as measured by incoherent scatter and 6300 Å airglow and total density derived temperatures used to compile the CIRA (1972) model or the molecular nitrogen density used for the GSFC Hedin et al., (1974) model. These measurements showed that very large changes in atomic oxygen boundary conditions occur throughout the auroral zone under disturbed magnetic conditions. These changes have been related to upward vertical fluxes of atomic oxygen. A similar problem with the seasonal anomaly had been investigated by Stubbe and his results have been adapted to the present problem. By the use of these velocities the energy transport out of the auroral zone can be estimated. The high latitude thermosphere can be considered using the number density continuity equation under storm conditions as a region of upwelling at the lower boundary and outward flow horizontally to lower latitudes. These winds have been examined using the southward component of the neutral wind at Millstone. It has been shown that the mass transport calculated from the two different data sets and in the different ways agree. It has been shown that the energy transport out of the auroral zone under active conditions by the wind system above 120 km amounts to about 3×10^{10} watts for a Kp value of 4. This is quite a large fraction of the estimated auroral heat input at these times and winds thus appear to be the major mechanism for transporting energy to lower latitudes.

A study has been made of spread F at Puerto Rico from ionograms and a series of incoherent scatter sounding observations made by Robert Harper of Arecibo. It has been determined that Arecibo is a most suitable site for studying spread F because the incidence is sufficiently variable that a series of observations can be conducted in which variable times of initiations can be obtained so that onset conditions can be investigated. A survey of the electric fields, winds, conductivities and density gradients has been made to compare the onset conditions for spread F with those predicted by the various theories. A study has been started with Dr. Zinchenko to compare the incidence of spread F at Puerto Rico and its magnetic conjugate location Port Stanley. These two stations are at very different geographic latitudes and so provide the opportunity for studying the role electric fields play in the initiation and propagation of spread F irregularities.

The coupling between two regions of high transverse conductivity separated by a region of low transverse conductivity is controlled by the coupling length. It has been shown that the coupling length between the two hemispheres is comparable with or smaller than the coupling length between the E and F regions at night. This means that a study of the degree to which spread F is correlated at the two ends of the field line will provide a good measure of the interaction not only of the conjugate ionosphere but also of the effect of the local E region. Initial indications are that the spread F incidence is not well correlated at the two ends of the field line and consequently the scale size of the irregularities dominating the build up of spread F are of size at least an order of magnitude smaller than 1 km. It also means that spread F is an F region effect and not just a symptom of an E region electric field structure.

1.2.1 Energy Balance of Nighttime Thermosphere - D. A. Glenar

Since my acceptance into the laboratory during November of last year, I have been examining the various contributions to the energy balance of the nighttime thermosphere. An abstract of this study, prepared jointly by Dr. Bleuler, Dr. Nisbet and myself, was submitted for presentation at the Annual Spring AGU Conference in April 1976 in a paper entitled "The Energy Balance of the Nighttime Thermosphere," by D. Glenar, E. Bleuler and J. S. Nisbet.

The argument for considering specifically the nighttime region of the thermosphere stems from the uncertainty in the energy input to the region from solar extreme ultraviolet (EUV) radiation. By considering the nighttime hemisphere alone, we have eliminated this uncertainty and allowed a comparison of the remaining energy input and loss terms.

In this study, we have spatially defined the nighttime thermosphere as the region between two concentric hemispheres surrounding the earth, the lower boundary lying at 120 km and the upper at 400 km above the earth's surface. The region is bounded on the sides by the morning and evening terminators. Under time invarient conditions, we may avoid a consideration of the detailed processes within the system and achieve an energy balance by equating the energy fluxes entering and leaving the system across these boundaries. High resolution incoherent scatter measurements have been used to estimate the downward energy conduction across the 120 km boundary. The flux across the terminator boundaries has been calculated using wind data obtained from sunrise-sunset vapor trail measurements and temperature and density distributions derived from incoherent scatter measurements at Arecibo.

Preliminary analyses suggest a discrepancy, the energy loss exceeding the sum of the energy input terms that were considered. This difference is explained, at least in part, by the deposition of gravity wave energy in the system. A large uncertainty in the energy balance is the extent to which the horizontal winds add energy to the system, particularly at high latitudes. Further work, then, involves the analysis of both additional incoherent scatter results and high latitude vapor trail measurements in an effort to minimize this uncertainty.

1.2.2 Thermosphere Boundary Fluxes - Dr. E. Bleuler

Since joining the laboratory in November, I have been developing programs and calculating terminator energy and particle fluxes for the study of the energy blaance of the nighttime thermosphere described by D. A. Glenar. A first-orientation calculation for a magnetically quiet equinoxial night, based on the CIRA 1972 (Jacchia) model, without winds, resulted in estimates of 144 GW for the thermal and gravitational energy gain through the terminator and of 30 GW and 85 GW respectively for the losses through the 120 km boundary due to mass transport (diurnal bulge settling) and thermal conduction. This would leave the proper order of magnitude of energy to be radiated. Calculations based on measured densities, winds, and temperature profiles for several days near the September 1974 equinox, however, show appreciable day-to-day variations in the energy balance. The calculations will be extended to include a much larger sample of observations in order to arrive at a better estimate of the average energy input through the boundaries.

1.3 Ultraviolet Airglow Emissions - R. Rohrbaugh

The period of October 1, 1975 to January 16, 1976 has been spent working at Goddard Space Flight Center under the guidance of Dr. J. R. Herman. During this time much of the preliminary work needed to calculate ultraviolet airglow emissions was completed. Specifically this entailed the collection of various photoelectron and photon excitation cross sections and the development of programs to calculate photoelectron and photo excitation rates. Programs have been written in general to be adaptive to any of the terrestrial planetary atmospheres and to any constituent giving rise to UV emissions by an appropriate change of the input parameters.

Work has also progressed in the development of the radiative transfer theory and the appropriate programming needed to transform the excitation rates into observational airglow intensities.

1.4 Upper Atmospheric Water Vapor - R. Longbothum

During this period, a computer simulation of stratospheric and mesospheric water vapor measurements has been completed. This program, based on radiative techniques in the microwave region of the electromagnetic spectrum, is now being used to analyze water vapor measurements from both a balloon and a limb viewing satellite. Work is proceeding on final thesis writing.

1.5 Mesospheric Processes - J. J. Olivero

The complete feasibility study for atmospheric water vapor measurements in the middle atmosphere, including inter- and extra-atmospheric viewing geometries, is nearly complete. Large research balloon experiments, particularly in the limb viewing mode, are attractive near term possibilities. Large satellite or space shuttle

configurations offer both flexibility and sensitivity throughout the middle atmosphere.

A highly accurate empirical relationship between the widths of the pressure (Lorentz) and Doppler broadened line and the Voigt line has been established as part of our atmospheric microwave radiative transfer model. We have achieved accuracies of $\pm$ 0.01% or better (Olivero and Longbothum, 1976).

The results of our current radiative transfer model for the summer polar mesospheric scattering layer are to be published in the Journal of Geophysical Research (Hummel and Olivero, 1976). More recent calculations including the wavelength dependence of the complex refractive index for ice suggests that our model brackets the effect, as we would have anticipated. However, our conclusions on possible polar climatic effects were drawn from larger scale solar radiation perturbations than we would accept at present.

References:

Hummel, J. R. and J. J. Olivero, Satellite observation of the mesospheric scattering layer and implied climatic consequences, J. Geophys. Res., 81, in press, 1976.

Olivero, J. J. and R. L. Longbothum, Empirical fits to the Voigt line width: A brief review, submitted to J. Quant. Spectros. Rad. Transfer, 1976.

1.6 Stratospheric Processes - M. Nicolet

A detailed study is being made of various problems dealing with the absorption of solar ultraviolet radiation in the spectral range of the Schumann-Runge bands of molecular oxygen. This study is particularly related to aeronomic problems of the stratosphere and mesosphere.

2. E and F Region

2.1.1 F Region Dynamics - L. A. Carpenter

A midlatitude model of electric fields was developed further as part of the Ph.D. thesis of Volker Kirchhoff. This model includes E region tidal winds from measurements by Dr. J. E. Salah at Millstone Hill and F region thermospheric winds from various models. The magnetic conjugate effect is considered to be communicated along perfectly conducting field lines, and the magnetospheric electric field is included as a current generator with an internal impedence large compared to the ionospheric resistances. The currents are deduced from the average DP2 variations according to Nishida et al., (1966), and the conductivities are calculated so the electric fields can be determined. The velocities calculated from this model reproduce those measured from Millstone Hill reasonably well.

During the daytime (0600-1800), the calculations reproduce both the north-south and east-west velocity with a high degree of accuracy. During the nighttime, the comparison is not as good, particularly during the early morning period. The southward velocity in the early morning may be the effect of an F-region dynamo since the ratio of Peterson E to F region conductivity is small and the thermospheric wind system drives the currents effectively. Large southward drifts have been measured occasionally and this effect may contribute to the large standard deviation in the measurements during this time. This work is written up as Scientific Report 438 on "Electric Fields in the Ionosphere" and is being submitted as a paper for publication.

The paper "Day-to-Day Variability in Ionospheric Electric Fields and Currents," by V. W. J. H. Kirchhoff and L. A. Carpenter is scheduled to appear soon in J. Geophys. Res., blue. In this paper, the variations in ionospheric drift velocities are examined from incoherent-scatter measurements at Millstone Hill. The data with $Kp > 24$ behaves differently from those at low magnetic activity and basically follows the convection pattern but has large day-to-day variations. The influence of the magnetic conjugate point is discussed and solar cycle variations are examined in conjunction with geomagnetic variations. Ionospheric currents calculated by using a semidiurnal neutral wind model are in good agreement with ground based magnetograms for low magnetic activity, but the E region neutral wind model appears to be applicable only to this case.

Work has begun on using electric fields and other measurements from incoherent scatter to distinguish between different theories of spread F. A proposal to examine data from Arecibo and make special measurements is in progress with Ed Klevans. George Imel and Gleb Zinchenko are currently examining data from Arecibo and finding some interesting and promising seasonal and solar cycle variations.

2.1.2 F Region Electric Fields - M. Miller

The comparison between the Stubbe and NRL ionospheric models was concluded.

Work was begun on a global ionospheric conductivity and current model. The time variations of the height integrated Hall and Pederson conductivities in the E and F regions will be determined by obtaining a two dimensional conductivity grid. Electric fields

imposed between various points on the grid cause a current system to be established. In this way the magnitude of the east-west and north-south currents as a function of distance from the source can be determined. Also the spatial configuration of the driving electric field can be studied. A computer program to calculate the conductivity grid was written. The grid of resistors derived from this program can then be analyzed using standard electric network analysis programs such as ECAP and SCEPTRE. Work was also done on the effects of conjugate coupling between hemispheres on the grid model. An effort is being made to determine the total resistance between the two hemispheres along a magnetic field line.

A paper is being written for publication based on a paper presented at the 1974 Fall AGU conference. The topic of the paper is the variation of solar EUV flux during a solar cycle. The variations as a function of F10.7 are determined using the Stubbe model and ionogram data.

2.2.1 Spread F Models - E. H. Klevans

Significant progress has been made in the past six months on analyzing theories of spread F. The theories have been reduced to a form suitable for comparison with Arecibo data on spread F. Eight days are being analyzed, four with spread F and four without. Data analysis to date reveals: (1) The equilibrium predicted by the Perkins model is reasonably well satisfied; (2) On several of these days, there is very poor agreement between the measured north-south neutral wind, and that predicted by a neutral wind model; (3) Horizontal gradients are too weak for the Ossakow model to apply; (4) The Perkins model gives the shortest growth times, typically around a half hour; (5) The Reid model predicts F region instability, but with very long growth times.

2.2.2 Spread F Models - G. Imel

This period was spent intensively studying three models of spread F: Perkins (1973), Reid (1968) and McDonald, et al., (1975). Data from Arecibo is being used to compare these three theories with regard to the predicted onset conditions and equilibria. A paper was presented at the Spring AGU meeting on these subjects.

Work is continuing on the data analysis, and new work has been started concerning possible E region contributions to the conductivities.

2.3 Spread F Observations - G. Zinchenko

The conditions necessary for the onset of midlatitude spread F were observed on the basis of Arecibo backscatter data. Previously the time characteristics of spread F at Arecibo were analyzed. Using the mentioned, the report on the spread F at Arecibo has been delivered at AGU Spring meeting in Washington, D. C. All this permitted us to make some recommendations as to the future special measurements to be done at Arecibo. Some characteristics of spread F at conjugate points (Puerto Rico - Port Stanley) were analyzed with the aid of ionosonde measurements.

It was shown that spread F incidence is markedly different at conjugate stations. This means that the coupling mechanism for the electric field which has been shown to be effective for lengths greater than 5 km between the hemispheres does not dominate the initiation or termination of the spread F observed. Hence the instability mechanisms must be dominated by scales much shorter than this.

2.4 E-Region Models - T. L. Stick

Work is being completed on my thesis to fulfill the requirements of an M.S. The topic of research is tides in the E-region.

3. D-Region

3.1 General - L. C. Hale

During this period we participated in the "Winter Anomaly" campaign of coordinated rocket measurements at Wallops Island. The first launch of a Super-Loki conductivity probe failed to separate and deploy on the parachute and hence no data was obtained from this payload which had previously been launched successfully and recovered at White Sands. A second Super-Loki performed nominally on an anomalous (high absorption) day and showed somewhat enhanced positive conductivity above 42 km. Thus all four of the Super-Loki conductivity probes have functioned satisfactorily, although the first of these in May 1975 produced data of questionable validity. The only difference in that payload was that it did not have the snap-shut shielding flap over the umbilical connector hole used on the other payload, thus demonstrating the extreme care necessary to prevent stray fields from invalidating the data.

Two more complex Astrobee-D payloads with ultraviolet ionizing radiation sources and Gerdien mobility analyzers deployed on 27' parachutes were launched on "normal" and "anomalous" days. The data from these flights have not yet been analyzed, but a quick look shows that the lamps created large amounts of ionization which were resolved into groups by the mobility analyzer.

A new design of Gerdien condenser payload was launched on a Super Arcas, at Poker Flat, Alaska, in February and performed nominally. The data are being analyzed.

3.2 General - A. J. Ferrar)

Several improvements in equipment now allow us to collect good quality cross-modulation data and computer process it. Operation was maintained during the 1976 Winter Anomaly; excellent results were obtained on two normal and two abnormal days. Since then, several all day runs were made and spectral analysis of data showed periods usually associated with gravity wave propagation.

Preparations are now being made for the Arecibo Heating experiment during July or August. Cooperative measurements are to be made with Drs. Gordon and Mathews.

3.3 General - H. S. Lee

Synthesis of electron density profiles from the wave interaction data obtained during the month of January, 1976 in conjunction with the joint Winter Anomaly Observation conducted at Wallops Island. These profiles were obtained with the new digitalized facilities with sample intervals as short as every two minutes. Preliminary evaluation appears to agree with anomalous and quite normal days predicted.

Revision of the paper titled "Intercomparison of Electron Density Synthesis Methods for Two Groundbased Techniques-Wave Interaction and Partial Reflection" was made and forwarded to J.A.T.P.

3.5 Arecibo Wave Interaction Measurements - M. Sulzer

Several all-day runs have been taken at Scotia using the completed new data-logging system. Computer analysis of the data has yielded interesting diurnal features in the data, and also the possibility, as yet unproven, of gravity waves. A plot of wave interaction data, and its power spectrum, from January 31, 1976 are shown. This particular day shows a rapid build up in data values before noon followed by the gradual diurnal decay. The dip occurring at 14:30 is associated with a sharp decrease in E layer critical frequency. Whether this indicates a coupling between the E and upper D layers is at present uncertain since there is some possibility the effect is caused by rapidly fluctuating wanted echo strength during this period.

Preliminary analysis indicates that the wave like structures (especially those just before noon) significantly exceed the noise level, and thus represent some kind of physically significant behavior. Further analysis is proceeding.

Presently, a system is being devised to convert an entire day of data to electron densities. The result will be plotted in a variety of two and three dimensional modes to make its features clearly viable. Also in progress are several equipment and software modifications for the Arecibo experiment this summer.

3.6 D-Region Theory and Measurements Below 70 km - A. Tomko

During this report period I have continued to investigate ionospheric modifications induced by high power radio waves and the application of modification techniques to the study of D-region attachment and recombination processes. I have completed a paper entitled: "A New Technique for Ionospheric Modification Studies,"

with M. Sulzer, H. S. Lee and A. J. Ferraro, and it has been submitted for publication. I am currently investigating the effects of strong electric fields on the electron velocity distribution function and subsequent corrections to the electron energy balance equation and the Sen-Wyller magnetoionic formulas.

3.7 Digitalization of WI and PR Experiments - K. Swanson

With the completion of the new wave interaction system data is now being taken in a routine manner. Preliminary results obtained during the Wallops Island winter D-region study and several all day runs have graphically demonstrated the improved capabilities of the new system. My Master's thesis on the study has been completed and I am now in the process of drawing up detailed schematics to document the system.

3.8 Arecibo H.F. Facility - J. Breakall

Throughout this period I have been continuing and have completed the major part of the work on the proposed HF facility at Arecibo and the analysis of the HF antenna to be installed at this location. I have been involved in this work since my stay this past summer at the NAIC at Cornell where I worked with Merle LaLonde and Bill Gordon on the design proposal for this facility.

A majority of the time here has been spent on the huge antenna modeling program (AMP) which we have acquired. This involved general de-bugging to work on our computer, learning how to use the program on known examples, and slowing putting each piece of the complicated heating array together. Bob Divany has been a tremendous help in making this monster of a program work on our computer system. After seeing this program work on the many examples we tried, one can begin to appreciate

the true power of this state-of-the-art program.

The HF array was analyzed for impedance characteristics and pattern first. This was done over the complete frequency range of the system. Results were compared with a model by LaLonde built at Cornell and also a model built here at Penn State. The experimental and computational results both agree very favorably. Two elements were then analyzed, and it was seen that the bandwidth improved. The analysis of the complete array is very complicated as far as computer computations are concerned, so a method was devised to find mutual impedances between elements separately and then add these impedances together in the correct combinations. This has been done for the center frequency, and it is found that the impedance varies largely from one element to another in the array. This creates some problems in matching which we are now conferring about with Gordon and LaLonde. The patterns of the array and gain compare almost exactly to those expected, however. We will be keeping in touch with Gordon and LaLonde on this project, and I will be continuing work on a more detailed report to be released.

4. Mass Spectrometer Measurements

4.1 Ion Analysis with Mass Spectrometers - General - B. Kendall

Several Types of mass spectrometers are being studied from both theoretical and experimental viewpoints, with a view to establishing their value for measuring the ionic composition in the D and lower E regions of the ionosphere. During this reporting period the main effort has again been devoted to work on time-of-flight analyzers having cylindrical and hemispherical electrodes.

Analysis of data from the May 1974 Nike-Apache flight (No. 14.482) indicates that a high proportion of the ions in the upper D-region have masses above 250 a.m.u. An additional experiment package to be flown on Nike-Cajun vehicle No. 10.317 is well advanced, although delays are being experienced due to accidental mechanical damage to vacuum lead-throughs and to the side-probe assembly. This package differs from the previous one in the following ways:

a) it will use a parachute to reduce the velocity in the upper parts of its trajectory, and to allow air-snatch recovery of the package;

b) a suppressor electrode is used to reduce photoelectric emission from the ion collector;

c) reduced draw-in potentials are used to reduce the possibility of cluster ion breakup;

d) the mass analyzer head will be protected by an evacuated housing in place of the nitrogen-filled housing used on the previous flight.

Several meetings were attended at Wallops Island regarding future plans. A renewal proposal was also prepared and submitted during the current reporting period.

4.2 Ion Analysis in the D and E Regions - R. Reiter

This reporting period has been spent calculating the effects of shock wave sampling problems, mass discrimination in time-of-flight mass spectrometers and the interference between the ion probes and mass spectrometer on the 14.482 sounding rocket data.

A study of the theory of shock wave production in the continuum flow regime was carried out by Walter Cuirle. Using the parameters calculated by Mr. Cuirle I have calculated the shock wave detachment distance, the stagnation point pressure and the average pressure inside the 14.482 mass spectrometer for angles-of-attack between 0 and 4.5 degrees. The angle-of-attack is the angle between the experiment package spin axis and the experiment package velocity vector. However, two serious problems prevent the direct application of these shock wave calculations to the 14.482 data. First, the experiment package angle-of-attack was almost always greater than 4.5 degrees and it was greater than 15 degrees during the upleg portion of the flight through the D-region. The use of any theory of shock wave production can not be justified for an angle-of-attack greater than about 7 degrees. Second, the experiment package was never in the continuum flow regime above 60 km. The 14.482 experiment package was in the transition flow regime from 60 km to about 110 km (on the upleg) and in free molecular flow above 110 km. However, the fact that the various flow regimes are distinguished mainly by the boundary conditions used for transverse flow means that the stagnation pressure calculations can be trusted. This is because the stagnation point pressure is considered independent of transverse flow effects. Also, the accuracy of neutral pressure calculations by Walt Cuirle using continuum flow theory up to 95 km suggests that continuum flow theory can be extended, at least in this case, to enable one to calculate the shock wave parameters. The extended continuum flow theory calculations of the shock wave parameters provide an upper limit on the pressure profile inside the 14.482 mass spectrometer.

Computer studies of mass discrimination, caused mainly by the use of gating, in the time-of-flight mass spectrometer studies in this laboratory show serious discrimination effects do not begin until ion masses greater than 500 amu are collected. The sensitivity of the cylindrical-electrode time-of-flight mass spectrometer is down by a factor of 2 at m = 500 amu. The sensitivity is down by a factor of 10 at m = 3000 amu.

Careful calculations of the interaction between the ion probes and the cylindrical-electrode TOFMS carried on the 14.482 experiment show these effects are not serious above 85 km (rather than 100 km as was mentioned previously) on the upleg. Therefore, data reduction was concentrated on the upleg data from 85 km co apogee.

The mass spectrometer data from the 14 .482 flight have been studied extensively in an attempt to deduce the presence of cluster ions and heavy ion (> 500 amu). These data show a complete lack of cluster ions with masses less than 500 amu (subject to sensitivity restrictions of the mass spectrometer) at any point in the D-region ionosphere. The data also indicates that essentially 100 per cent of the ions present up to 90 km have masses greater than 500 amu. These results confirm an earlier measurement, reported previously by Dr. B. R. F. Kendall, by another cylindrical-electrode TOFMS. It is my conclusion that the cluster ions normally present in the D-region (and extending up to 95 km) are almost all very heavy (> 500 amu). It is entirely possible that there is almost a continuum of mass numbers represented without a particularly concentration at each mass number. But when these heavy ion concentration are added up, the total concentrations are significant.

These very heavy ions are not necessarily of the form of $H_3O^+ \cdot (H_2O)n$ but could be water clusters of other ions (especially NO^+ and metallic ions) or even water clathrates. The discussion of these results and the justifications for my conclusions will be presented in my Ph.D. thesis which will be completed in June of this year.

A follow-up sounding rocket experiment package, essentially identical to the 14.482 payload, is scheduled for launch in June, 1976. This experiment package will be flown with a parachute and should produce subsonic mass spectrometer data with greater sensitivity for comparison with the 14.482 results.

4.3 Ion Dynamics of Pulsed Mass Analyzers - B. R. F. Kendall

This project has been temporarily inactive following the completion of R. Stein's Ph.D. thesis and the publication of key portions of it during 1974. The work has recently been revived by R. F. Reiter and S. Rossnagel. The results are being incorporated into R. F. Reiter's Ph.D. thesis.

4.4 Deconvolution

This project is temporarily inactive due to lack of funding.

4.6 Constant-Momentum Mass Analyzers - B. R. F. Kendall (for Yee Seung Ng)

A review of existing publications on this topic has been made. A gas handling system has been designed and constructed for use with an existing vacuum system in which tests of various kinds of constant-momentum mass spectrometers will be made. The necessary electronic equipment has been collected and an experimental constant-momentum mass spectrometer with an electron bombardment ion source has been constructed.

Present activity is being devoted mainly to the identification of processes leading to an excessive ion energy distribution in the ions emitted from the ion source. Elimination of this unwanted energy is essential before meaningful tests can be carried out on the constant-momentum portion of the apparatus.

4.8 Brownian Motion/Diamagnetic Levitation - B. R. F. Kendall

The joint paper with R. S. Butler is in the final stages of preparation. Evrard and Boutry, who published one of the original papers on this subject, have been informed of an apparent minor error in their theoretical derivations.

Apparatus for levitating graphite particles and observing their random motions at low pressures has been assembled in Davey Laboratory by S. Rossnagel and will be used during the coming months for experiments at lower pressures than we have previously used.

4.9 Mass Filters - B. R. F. Kendall

A study has been made of early papers regarding the low-pass mass filter principle originally described by Eiber in 1953. There is experimental evidence that probes of this type should be operable at altitudes as low as about 40 kilometers without the need for differential pumping. A proposal is being prepared with a view to evaluating this type of mass-selective ion probe for use in rocket experiments in the upper stratosphere.

5. Direct Measurements

5.2 Methods of Minor Constituent Measurements - C. Croskey

The first part of this period was spent completing my doctoral thesis "In Situ Measurements of the Mesosphere and Stratosphere" which was successfully defended in November.

Two Super Loki plunt probes were then readied for the Winter Anomaly program at Wallops Island, Virginia. Work was also contributed to the completion of two Astrobee-D payloads for the same program. Several weeks were spent in field support of the Winter Anomaly program in January.

A small Super Loki Gerdien condenser based on the electronics from the Super Loki system was developed for flight from Poker Flat, Alaska.

The reduction of data from four Super Loki blunt probe flights was completed.

5.7 Synoptic Payload Design - R. Scott

Work has continued along the lines of decreasing noise in data through payload design changes. Advancements have been made in the areas of signal to noise ratio analysis and possible hardware changes. I am continuing along these lines with a hopeful completion by late August 1976.

5.9 Gerdien Condenser Analysis - S. Leiden

The analysis of three Gerdien condenser flights and one blunt probe has been completed. The results of this analysis are being implemented into a dynamic model of the D-region as proposed by Dr. Leslie C. Hale and Dr. E. T. Chesworth. This model is presently being studied on the 680 analog computer. Results from the model simulation are expected within the next few weeks. The total of this research is also being compiled in the authors thesis work.

6. Atmospheric Reactions

6.1 The Reactions of HO_2 with NO and NO_2 - R. Simonaitis

The study of the reactions of HO_2 with NO and NO_2 has now been completed (see Semi-Annual Status Report No. 2 for details of this study). A complete analysis of the data in the temperature range of 245^{o}-$328^{o}K$ has now been carried out. Absolute values of the rate coefficients k_{26}, k_{-26} and k_{106} as a function of temperature were obtained.

6.3 The Photooxidation of Formaldehyde - T. Osif

It was thought that the reaction mechanism for the photooxidation of formaldehyde was understood. However, some recent results have been obtained which can not be explained by this mechanism. There formaldehyde has been photolized at 3130A in the presence of air at various formaldehyde and air pressures. Studies were done at different temperatures and sometimes radical scavengers were added in an attempt to gain some clues as to the correct mechanism. Carbon monoxide, carbon dioxide, hydrogen, and formic acid were the reaction products measured

6.4 The Reaction of NH_2 with NO_2 - R. K. M. Jayanty

NH_3 was photolyzed at 213.9 nm in the presence of NO_2 at $25^{o}C$ in order to study the reactions of NH_2 with NO_2.

$$NH_3 + h\nu \rightarrow NH_2 + H$$

The products included NO, with a quantum yield of 1.0, and it can be attributed to the reaction

$$H + NO_2 \rightarrow HO + NO$$

The other measured products of the reaction were N_2 and N_2O with respective quantum yields of 0.94±0.10 and >0.3 in the presence of small amounts of He (∿ 5 torr) and 0.65± 0.15 and > 0.13 in the presence of a large excess of He. The quantum yield for NO_2 consumption was 6.0 ±2.0 in the absence of He. These results are explained in terms of the reactions

$$NH_2 + NO_2 \rightarrow N_2O + H_2O \qquad 4a$$
$$\rightarrow N_2 + 2OH \qquad 4b$$
$$\rightarrow N_2 + H_2O_2 \qquad 4c$$
$$\rightarrow 2HNO \qquad 4d$$
$$\rightarrow \text{Solid or undetected product ultimately} \qquad 4e$$

The relative importance of the reaction channels are $(k_{4a} + k_{4d})$ $(k_{4b} + k_{4c})$ > 0.3 in the presence of small amounts of He (5 torr) and > 0.20 in the presence of large excess of He. The ratio $K_{4b}/k_4 \simeq$ 0.34 if $k_{4c} = 0$ or $k_{4c}/k_4 \simeq 0.42$ if $k_{4b} = 0$. Reaction channels $4_a - 4_d$ account for > 65% of the reaction. The overall rate coefficient for reaction 4 is larger than for the NH_2 - NO reaction, i.e. > (2 ± 1) x 1[illegible] cm^3 sec^{-1}.

B. SUPPORTING OPERATIONS

102.1 R. Divany

As a follow-up to processing of cross modulation data from Arecibo a series of experiments were performed at Scotia to gather noise data. A program was prepared to process the noise data tapes and another to do further averaging and write a tape for Fourier processing.

A program for determining reaction rates was developed. It used a non-linear parameter estimation program in conjunction with a differential equation solving program.

Several programs were written to process Scotia data gathered during the Winter Anomaly program.

Some modifications were made to the ray-tracing program to look at effects caused by ionospheric heating by a ground based transmitter.

Programs for sorting F2 peak data from Alouette I and Alouette II and for comparison with CCIR model predictions were written and run to yield numerous plots. This resulted in a computer program which modified the CCIR model to include the main trough.

AMP - a sophisticated antenna modeling program was adapted to the IBM System/370 and extensive tests were made to model a proposed HF antenna for Arecibo.

Some preliminary work has been done to examine N_2, O_2 and He density data from OGO VI. The next step is to check to see exactly what time periods the data covers.

102.2 B. Beiswenger

Much miscellaneous work was done for various personnel during this period. Spread F was identified on paper ionograms and films from Arecibo for Dr. Zinchenko and about 200 graphs of electron density profiles and other data were plotted for him. We worked with Dr. Simonaitis to get desirable convergence values for K_{-2B} and K_{10B} for his temperature dependence study. Tapes of the Scotia wave interaction data were processed using Dale synthesis for the Winter Anomaly Study sponsored by Dr. Lee and Dr. Ferraro. The Science Citation Index at Pattee Library was consulted to list all sources of and to tabulate the number of citations (first author only) from 1971 to 1975 for all IRL faculty. For the same IRL review committee, papers published were accredited to first author and

coauthor(s). Graphs and assorted tasks were done for B. Halcrow and Dr. Bleuler, and work was done for J. Breakall on the Antenna Modeling Program.

104 Library

104.1 L. Shapira

Four Scientific Reports have been received and distributed (439, 440, 441 and 442).

Twenty reprints written by staff members have been received into the library.

C. OTHER ACTIVITIES

201 Publications and Presentations

201.1 Scientific Reports

439 Kirchhoff, Volker. W. J. H. and L. A. Carpenter, Calculation of Conductivities and Currents in the Ionosphere, November 28, 1975.

440 Nicolet, Marcel, Stratospheric Ozone: An Introduction of its Study, November 21, 1975.

441 Tomko, Albert A., A Study of the Electron Density Distribution in the Lower D-Region and its Aeronomic Implications, January 9, 1976.

442 Croskey, Charles, In Situ Measurements of the Mesosphere and Stratosphere, January 16, 1976.

201.2 Papers Published

456 Kissick, W. A. and A. J. Ferraro, Self-heating of the partial reflection experiment, J. Atmos. Terres. Phys., 37, 1365-1370, 1975.

457 Jayanty, R. K. M., R. Simonaitis and Julian Heicklen, The photolysis of cholrofluoromethanes in the presence of O_2 or O_3 at 213.9 nm and their reactions with $O(^1D)$, J. Photochem., 4, 341-360, 1975.

458 Weaver, James, James Meagher, Robert Shortridge and Julian Heicklen, The oxidation of acetyl radicals, J. Photochem., 4, 341-360, 1975.

459 Hisatsune, I. C. and Julian Heicklen, Infrared spectroscopic study of ammonia-sulfur dioxide - water solid state system, Canadian Journal of Chemistry, 53, 17, 2646-2656, 1975.

460 Nicolet, Marcel, Stratospheric ozone: An introduction to its study, Reviews of Geophysics and Space Physics, 13, 5, 593-636, 1975.

461 Simonaitis, R. and Julian Heicklen, Perchloric acid: A possible sink for stratospheric chlorine, Planet. Space Sci., 23, 1567-1569, (1975).

462 Smith, Roland, R. G. DePena and Julian Heicklen, Kinetics of particle growth; VI. Sulfuric acid aerosol from the photooxidation of SO_2 in moist O_2 - - N_2 mixtures, J. of Colloid and Interface Science, 53, 202-213, 1975.

463 Nisbet, J. S., Comment on 'Electron densities between 110 and 300 km derived from solar EUV fluxes of August 23, 1972' by L. Heroux, M. Cohen and James E. Higgins, J. Geophys. Res., 80, 34, 4770, 1975.

464 Stockburger, L., III and J. Heicklen, The inhibition of photochemical smog -- IV. Effect of diethylhydroxylamine on particle production, Atmospheric Environment, 10, 51-55, 1976.

465 Simonaitis, R. and Julian Heicklen, Reactions of HO_2 with NO and NO_2 and of OH with NO, Journal of Physical Chemistry, 80, 1, 1976.

466 Sie, B. K. T., R. Simonaitis and J. Heicklen, The reaction of OH with NO, International Journal of Chemical Kinetics, 8, 99-106, 1976.

467 Jayanty, R. K. M., R. Simonaitis and Julian Heicklen, H_2 formation in the reaction of $O(^1D)$ with CH_4, International Journal of Chemical Kinetics, 8, 107-110, 1976.

468 Sie, B. K. T., R. Simonaitis and Julian Heicklen, The reaction of OH with CO, International Journal of Chemical Kinetics, 8, 85-98, 1976.

469 Jayanty, R. K. M., R. Simonaitis and Julian Heicklen, Reaction of NH_2 with NO and O_2, Journal of Physical Chemistry, 80, 433, 1976.

470 Osif, Terry L., R. Simonaitis and J. Heicklen, The reactions of $O(^1D)$ and HO with CH_3OH, Journal of Photochemistry, 4, 233-240, 1975.

471 Whitehead, J. D., The partially aligned gradient instability in the ionosphere, Journal of Geophys. Res., 81, 1361-1368, 1976.

472 Blume, Cary W., I. C. Hisatsune and Julian Heicklen, Gas-phase ozonolysis of cis- and trans-Dichloroethylene, International Journal of Chemical Kinetics, 8, 235-258, 1976.

473 Monro, P. E., J. S. Nisbet and T. L. Stick, Effects of tidal oscillations in the neutral atmosphere on electron densities in the E-region, J. Atmos. Terres. Phys., 38, 523-528, 1976.

474 Stockburger, Leonard, III, B. K. T. Sie and Julian Heicklen, The inhibition of photochemical smog, V. Products of the diethylhydroxylamine inhibited reaction, The Science of the Total Environment, 5, 201-222, 1976.

475 Olszyna, Kenneth and Julian Heicklen, The inhibition of photochemical smog, VI. The reaction of O_3 with diethylhydroxylamine, The Science of the Total Environment, 5, 223-230, 1976.

201.3 Papers Presentei

Nisbet, J. S., Equatorward thermospheric winds at midlatitudes, oxygen depletion at hgih latitudes and heating at low latitudes, Fall AGU Meeting, San Francisco, December 7, 1975 - December 13, 1975.

Wydra, B., Global exospheric temperatures and densities under active solar conditions, Fall AGU Meeting, San Francisco, December 7, 1975 - December 13, 1975.

Kirchhoff, V. W. J. H. and L. A. Carpenter, Model of midlatitude electric field, Fall AGU Meeting, San Francisco, December 7, 1975 - December 13, 1975.

202 Seminars

Dr. Manfred A. Biondi, University of Pittsburgh, Laboratory Determination of Temperature Dependence of Reaction Rates of Aeronomical Interest, January 15, 1976.

Charles L. Croskey, In Situ Measurements of the Mesosphere and Stratosphere, February 13, 1976.

Dr. Gene W. Adams, The National Science Foundation, Transport of Excited Species, March 8, 1976.

Dr. Gleb N. Zinchenko, Kharkov State University, F-Region Irregularities at Arecibo, March 12, 1976.

203 Visitors

Dr. Gleb N. Zinchenko, Radiophysical Department, Kharkov State University, U.S.S.R., September 4, 1975 - May 21, 1976.

Dr. Manfred A. Biondi, University of Pittsburh, Pittsburgh, Pennsylvania, January 15, 1976.

Dr. Marcel Nicolet, Director, Institute D'Aeronomie, Brussels, Belgium, March 12, 1976-March 15, 1976.

D. PERSONNEL

Name	Title	Percent Funded Time	Problem
The National Aeronautics and Space Administration			
Grant NGL 39-009-003 - NASA IRL MD - 5935			
J. S. Nisbet	Prof. of Elec. Eng. Director, IRL	28.8	2.1
E. Bleuler	Prof. of Physics	- -	1.2.2
J. Heicklen	Prof. of Chemistry	--	--
L. A. Carpenter	Asst. Prof. of Elec. Eng.	35.4	2.3
J. J. Olivero	Asst. Prof. of Meteorology	50.0	1.7
E. H. Klevans	Associate Prof. of Nuclear Eng.	8.3	3.4
R. Simonaitis	Research Associate	55.0	6.1
R. Jayanty	Postdoctoral Scholar	41.6	6.4
J. Breakall	Graduate Assistant	16.7	1.12
D. Glenar	Graduate Assistant	66.6	1.2.1
G. Imel	Graduate Assistant	100.0	4.10
M. Miller	Graduate Assistant	100.0	2.13
R. Rohrbaugh	Graduate Assistant	16.7	2.7
T. Stick	Graduate Assistant	100.0	2.12
K. Swanson	Graduate Assistant	16.7	1.14
A. Tomko	Graduate Assistant	16.7	1.13

Name	Title	Percent Funded Time	Problem
Grant NGL 39-009-002 - NASA SATELLITE - 5972			
W. J. Ross	Prof. of Elec. Eng.	--	2.2, 3.13
R. Longbothum	Instructor in Elec. Eng.	--	1.9
Grant NGR 39-009-032 - NASA CMMS IX - 5918			
B. R. F. Kendall	Prof. of Physics	42.0	4.1, 4.7
Grant NAS6 - NASA DART - 5922			
L. C. Hale	Prof. of Elec. Eng.	17.7	1.2
C. Croskey	Postdoctoral Scholar	74.1	5.2
R. Scott	Graduate Assistant	100.0	5.7
Grant NGR 39-009-218 - NASA MESO III - 5941			
S. Leiden	Graduate Assistant	66.6	5.9
Grant NSG - 6004 - NASA MAP - 5945			
L. C. Hale	Prof. of Elec. Eng.	17.7	1.2
C. Croskey	Postdoctoral Scholar	11.7	5.2
S. Leiden	Graduate Assistant	33.3	5.9

The National Science Foundation

Name	Title	Percent Funded Time	Problem
Grant CA 33446 X2 - NSF FOUNDATION - 6303			
J. S. Nisbet	Prof. of Elec. Eng.	--	2.1
A. P. Mitra	Consultant	--	1.5
M. Nicolet	Consultant	1 day	1.4
O. E. H. Rydbeck	Consultant	--	--
P. Stubbe	Consultant	--	2.4
R. Rohrbaugh	Graduate Assistant	88.3	2.7

Name	Title	Percent Funded Time	Problem
Grant CA 33446 X2 - NSF FOUNDATION - 6303 (Con't)			
K. Swanson	Graduate Assistant	16.7	1.14
A. Tomko	Graduate Assistant	33.3	1.13
Grant GR 41854 - NSF D-REGION MEASUREMENTS - 6243			
A. J. Ferraro	Prof. of Elec. Eng.	4.2	1.1
H. S. Lee	Prof. of Elec. Eng.	8.3	3.1
A. Tomko	Graduate Assistant	50.0	1.13
J. Breakall	Graduate Assistant	33.3	1.12
M. Sulzer	Graduate Assistant	100.0	1.11
K. Swanson	Graduate Assistant	83.3	1.14

The Office of Naval Research

Name	Title	Percent Funded Time	Problem
Grant N00014-67-A-0385-0014 - DN INTERACTION - 7073			
A. J. Ferraro	Prof. of Elec. Eng.	2.5	1.1
H. S. Lee	Prof. of Elec. Eng.	2.5	3.1
Grant N00014-75-C-0971 - DN D-REGION - 7132			
A. J. Ferraro	Prof. of Elec. Eng.	12.5	1.1
H. S. Lee	Prof. of Elec. Eng.	12.5	3.1
J. Breakall	Graduate Assistant	50.0	1.12
A. Tomko	Graduate Assistant	33.3	1.13

Department of the Army

Name	Title	Percent Funded Time	Problem
Grant DAHCO4-75-G-0031 - DA AERO - 4400			
L. C. Hale	Prof. of Elec. Eng.	17.7	1.2
C. Croskey	Postdoctoral Scholar	3.8	5.2